

SMART TEACHING STRONGER LEARNING

Practical Tips From 10 Cognitive Scientists

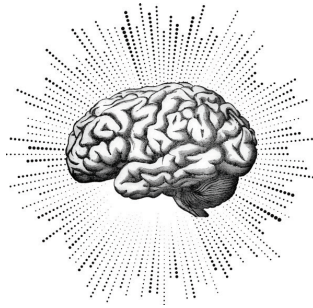


Edited by Pooja K. Agarwal, Ph.D.

Lead author of *Powerful Teaching*

SMART TEACHING STRONGER LEARNING

Practical Tips From 10 Cognitive Scientists



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Smart Teaching Stronger Learning: Practical Tips From 10 Cognitive Scientists

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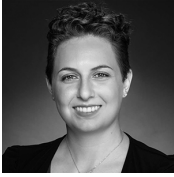


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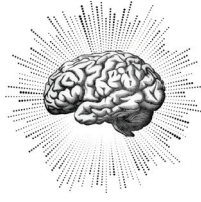


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3

Spaced Practice

Optimize Class Time to Boost Learning

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Conventional wisdom tells us that the key to mastery is to spend more time learning; if your student performs poorly on an exam, they are likely to spend more time studying for the next one. And if you notice your students struggling to grasp a difficult concept, it makes sense to spend more time teaching that concept. But is more time spent studying and teaching better for learning?

Surprisingly, not always. Research reveals that the key to successful learning is *not* the total time spent learning, but the *way* in which that studying and teaching time is used.¹ In this chapter, I discuss how to use *spaced practice* to improve learning without changing the amount of time spent learning. Spaced practice is supported by hundreds of studies and over a century of research. It is simple and easy to implement, it works for any type of learning, and it improves students' long-term learning.

Research on Spaced Practice

Spaced practice (also called *spacing*) involves strategically arranging time spent learning into multiple sessions that are spread out over time. This can be compared to the more popular approach — known by many as cramming — in which students do most or all of their studying in one long session shortly before an exam.^{2,3}

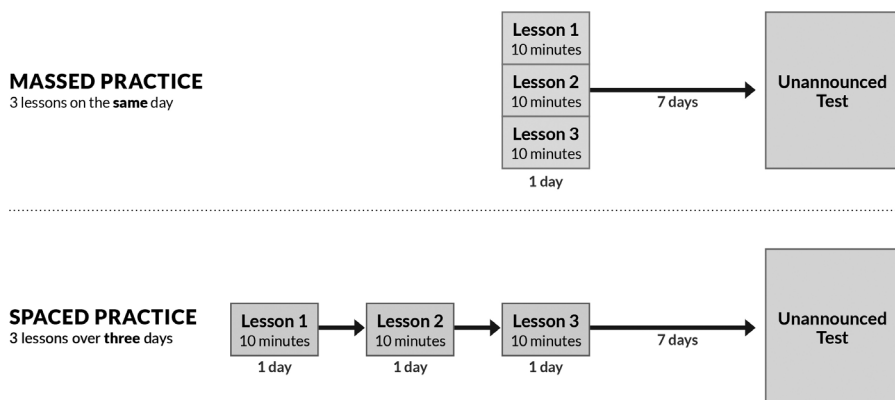
For example, in preparation for a Spanish exam, a student might study 50 vocabulary words by repeatedly trying to retrieve the English translation for Spanish words (e.g., Zapato – Shoe). Let's say the student goes through the whole list three times retrieving the translations the night before the exam. An alternative approach is to practice retrieving the list of vocabulary words on three separate occasions: a week before the exam, again a few days later, and again a few days after that. Both approaches involve the same amount of time learning, but they differ in how that time is scheduled.

Research shows that simply spacing out learning opportunities across multiple days leads to much higher achievement than learning the same amount of information all in one session. In one classroom study, middle school students retrieved information from their science lessons either right after the lessons ended or a few days after the lessons. On exams given at the end of the semester a few months later, students performed better when retrieval practice was spaced a few days after the lessons instead of right afterwards.⁴

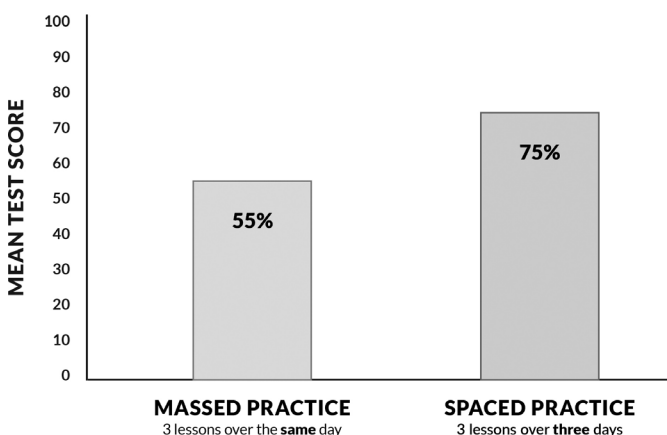
In research I conducted with colleagues, middle school students answered questions about information from their history class either soon after they learned the material or several weeks after they learned it. When both groups were given an unexpected test nine months later, the group that reviewed after several weeks scored significantly higher.⁵ Maintaining knowledge over the course of a semester or after a nine-month interval — equivalent to an academic year at many schools — shows that learning information through spaced practice leads to long-lasting and durable learning over time.

In another research study, high school students learned French vocabulary words back-to-back on the same day for 30 minutes (massed practice), or once per day over three days for 10

minutes each (spaced practice). Several days after the exercises were completed, all of the students were given an unannounced test.



Contrary to what you might expect, students who completed the exercises with spaced practice across three days performed better (75%) than students who completed the exercises with massed practice on the same day (55%).⁶ In other words, even though the two groups of students spent the same amount of time learning the material, the group that spaced out their practice over multiple days learned French significantly better.



Why Spacing Works

Cramming increases the amount of information in short-term memory, but it does not improve long-term memory. When students engage in immediate repetition, information quickly becomes familiar — what scientists call an *illusion of knowing*. Unfortunately, when information is quickly acquired, it's often quickly forgotten. It can be much more difficult to remember the information after a week, or even a day.

On the other hand, when learning opportunities are spaced apart, students engage in increased effort to retrieve the information, which improves the durability of learning — what scientists call a *desirable difficulty*. Retrieving information across sessions is more challenging and students have to try harder to remember it. This can lead students to feel like they are not learning very well from spaced practice, but that's precisely why spacing works: The challenge from spacing significantly improves long-term learning.

Spacing Improves Transfer of Knowledge

Spaced practice improves students' long-term learning of academic knowledge and skills in a variety of subject areas, including language, math, science, and social studies.⁷ Students who engage in spaced practice learn concepts better and show enhanced understanding — not just memorization — of how concepts apply to new situations. Being able to apply knowledge to a new situation is known as *transfer of learning* and it is an important goal of education (see also Chapter 8).

For example, in one study, elementary school children learned scientific information about food chains, such as the tendency for larger animals to eat smaller animals and the tendency for the number of species to increase when they have more food to eat. The children received four lessons that involved hands-on demonstrations and questions about the information they were learning. The four lessons occurred on the same day (massed practice) or once per week across four weeks (spaced practice). As expected, children who received the

once-per-week spaced lessons learned the information better than children who received the lesson all in one day (see Chapter 2 about retrieval practice in early childhood education).⁸

In addition, on a later test over what they had learned, the spaced group performed better on questions over the basic concepts (for example, “Bigger animals typically eat ____ animals”), simple transfer questions (“What does the frog eat?”), *and* questions that required fairly complex transfer (“Let’s say that all the frogs get captured and taken away by hunters. What happens to the number of turtles? Does it go up, down, or stay the same?”). Thus, spaced practice improved children’s ability to not only retain knowledge they learned, but also to use that knowledge in different ways.

Spaced practice benefits many types of learning, from young children learning their first concepts about the world, to medical students learning how to perform surgical operations. One study found that medical students were more successful in performing a surgery if they had practiced surgical skills in four spaced sessions that occurred once per week over four weeks, compared to four sessions that occurred on the same day.⁹ For a patient undergoing surgery, the value of spaced practice cannot be overstated!

Strategies to Implement Spaced Practice

The key to implementing spaced practice is to engage students with material on multiple occasions that are separated in time. This can be done in a number of ways:

Break Up Lessons into Smaller Sessions

Instead of teaching one long lesson over a topic, divide up the lesson into smaller lessons and space them over multiple days. For example, in teaching students to conjugate verbs in a foreign language, conjugation rules can be introduced and practiced in a brief session, followed by additional practice with the same rules on subsequent days. The same goes for any academic material, such as practicing mathematical procedures, recalling terms and definitions,

comparing and contrasting different concepts, or generalizing knowledge to new situations.

Revisit Concepts From Previous Lessons

It makes sense to think that once a topic has been covered, there is no need to cover it again. To the contrary, students who are learning information for the first time need to revisit it, think about it more, and process it multiple times. Such opportunities can be provided by working into class lessons some of the concepts that had been encountered in previous lessons. These can take the form of class discussions, class activities, or homework assignments that require students to retrieve previously learned information and relate it to new concepts.

Harness Technology for Spaced Study Schedules

Students can use a number of accessible online tools, such as online flashcards or calendars, to create and set a schedule with built-in reminders for studying information. With the help of learning management systems, you can also set daily quizzes designed to provide spaced retrieval practice of the concepts being learned.

Include Cumulative Retrieval Practice

Cumulative quizzes and exams facilitate spaced practice by including concepts learned at earlier points in the course. They also encourage students to study previously learned information in order to prepare for the exams. Always make sure to use spacing as a *learning* strategy throughout the semester or school year, not simply as part of high-stakes assessments.

Potential Challenges

Learning Can Feel Slow and Ineffective

When students try to retrieve information after time has passed, they will notice that they have forgotten some (or even most)

of it. This could create a sense of discouragement and the feeling that they are not learning. In reality, however, information that was once learned can be re-learned more quickly with less effort, optimizing study time over time.

Spacing Can Require Some Planning

When you incorporate spacing into your classes, you might find it challenging at first to cover smaller portions of information across multiple days or to incorporate previously taught concepts into current lessons. Structuring a class to incorporate spaced practice requires some planning. Importantly, however, it does not require major restructuring or overhauls to the course, but rather a redistribution of the same amount of time that will already be spent on each lesson.

Students May Not Use Spaced Practice on Their Own

Students often opt to study information by cramming a couple of days before the exam. To encourage spaced studying, provide retrieval practice activities or brief assignments on a daily or weekly basis, rather than only one or two major exams.

Frequently Asked Questions

What is the optimal amount of spacing?

In general, the more, the better. Spaced practice is beneficial whether the lessons occur on consecutive days, one week apart, or even several weeks apart. Research shows that any spacing is better than no spacing, and exactly how much time should occur between learning sessions or the total number of sessions is less critical. You and your students should strive to space information across multiple days at long enough intervals that learning feels challenging. Importantly, these intervals can be flexible and adjusted according to your course schedule and the specific material being learned.

Should the amount of spacing stay the same or increase each time?

Research shows that the timing between sessions, whether it stays the same or increases over time, does not have a large effect on classroom learning. Students can complete two lessons with one day in-between, with five days in-between, and so on. Compared to learning the information in a single longer session, spacing benefits learning regardless of whether the time between lessons is equal or variable.

What should students do in between spaced study sessions?

Spacing benefits learning and exactly how time is spent between study sessions or lessons is less critical. For example, if students practice conjugating verbs in Spanish with spaced study sessions, they can engage in any number of activities in between, such as learning history, science, or mathematics. In fact, research has shown that alternating similar content during spaced study sessions (called *interleaving*; see Chapter 4) improves learning by providing practice at comparing and contrasting.¹⁰ With interleaving, a student could even use the in-between time to practice conjugation in French to provide an added benefit when learning Spanish.

What should students do during spaced study sessions?

Although spacing still benefits learning even when students acquire information purely through reading or listening to a lecture, spacing is even more effective when students learn by using retrieval practice.¹¹ When students try to recall information, instead of just reading it, they learn it much better. In particular, repeated attempts to retrieve and review informative feedback are particularly effective for building solid long-term learning and reliable transfer of knowledge.

Further Reading

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Carpenter, S. K., Pan, S. C., & Butler, A. C. (2022). The science of effective learning with spacing and retrieval practice. *Nature Reviews Psychology*, 1, 496–511.

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Dr. Shana Carpenter (she/her) is a Professor of Psychology at Oregon State University near Portland, Oregon. Dr. Carpenter teaches courses and advanced seminars on introductory psychology, cognitive psychology, and research methods. She specializes in research on cognitive science principles that can be applied in classrooms to help students retain information, transfer what they have learned to new situations, and improve their awareness of their own learning. Dr. Carpenter is the author of over 70 published journal articles and book chapters, and her work has been featured in *The Washington Post*, *Forbes*, and *The Chronicle of Higher Education*. She earned her Ph.D. from Colorado State University.

Learn more about Dr. Carpenter at <https://retrievalpractice.org/carpenter> and follow her on X (formerly Twitter) at @ShanaKCarpenter.



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Chapter 3: Spaced Practice

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In *Smart Teaching Stronger Learning*, renowned cognitive scientists from around the world share innovative teaching strategies that significantly **transform student learning**. This approachable resource distills key principles from the science of learning, with concise chapters and real-world examples for busy educators and leaders in K–12, higher education, and beyond.

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Pooja K. Agarwal, Ph.D. (editor) is a cognitive scientist and lead author of the book *Powerful Teaching: Unleash the Science of Learning*. Her award-winning research on how students learn has been published in prominent academic journals; featured in *The New York Times* and *NPR*; and recognized by the U.S. Department of Education. Drawing on her combined 20 years of experience as a scientist, public school teacher, and college professor, Dr. Agarwal shares practical research-based resources for thousands of educators around the world at *RetrievalPractice.org*.

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